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Review Article

A review on comparing various test methodologies and target types for measuring near point of convergence

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Abstract

This study aims to evaluate the variability in near point of convergence (NPC) break and recovery values across different methodologies and populations to improve the understanding of convergence insufficiency (CI) diagnosis. It seeks to analyze the influence of factors such as age, font size, repetition, and testing distance on NPC values. Additionally, the study highlights the inconsistencies in assessment methodologies currently used in CI diagnosis, which can affect the reliability and accuracy of NPC measurements. Convergence insufficiency (CI) is a common vergence anomaly, affecting 0.85-13% of the population. Prolonged near work can lead to excessive accommodation and vergence, resulting in diminished binocular functions and symptoms such as asthenopia, headaches, and eyestrain. A comprehensive literature review from sources such as PubMed, PubMed Central, and ResearchGate revealed significant variations in NPC values. Despite being a widely used diagnostic tool, NPC assessment lacks standardized protocols. The variability in NPC break and recovery values across different studies suggests inconsistencies in testing methods, including differences in target characteristics, age groups, and testing conditions. There is a need for a more standardized approach to improve the reliability and clinical applicability of NPC measurements. The lowest break value recorded was 5 cm using a 9-point font size objective, whereas the highest recovery point reached 15.03 cm with a long scale and accommodative target in individuals aged <5 to 85 years. These findings underscore the need for standardized NPC assessment protocols to enhance the accuracy of CI diagnosis and management.

Keywords: Near point of convergence, Methodologies, Target selection, Break and recovery values.

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1. Introduction

Convergence is the only conscious disjunctive fusional movement that can be triggered by intention, differential stimulus, or accommodation. Convergence insufficiency (CI) is the most prevalent vergence anomaly, with rates ranging from 0.8% to 13% in various studies.[1-6]

Near point of convergence (NPC) refers to the highest amplitude of convergence or the nearest point at which a person can sustain picture fusion. It consists of two phases: the break point occurs when an object approaches a subject slowly and the subject experiences diplopia and the recovery point arises when the target moves gradually and the object is seen plainly.[7-10]

Patients who read frequently on their smartphones, tablets, and computers may experience ocular conditions related to near work that needs to be examined.[11] Excessive accommodation and vergence at near work can result in a decline in binocular functions, such as diminished fusional vergence, as well as symptoms such as Asthenopia, headache

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and eyestrain, loss of concentration, or intermittent diplopia.[12] NPC is a useful sign for diagnosing CI and distinguishing between symptomatic and asymptomatic instances.[13]

During an eye exam, near point of convergence (NPC), horizontal phoria, and fusional vergence are frequently measured to diagnose binocular anomalies.[14] 36% of the studies included a receding near point of convergence as a crucial diagnostic criterion.[15] Evidence suggests that NPC was employed in making the diagnosis of convergence insufficiency by 93.8% of optometrists assessed and that the most commonly utilized single diagnostic criteria was the NPC, with 35% of the clinicians indicating that one criterion was sufficient to diagnose convergence insufficiency.[16]

The research on near point of convergence from 1886 to 2023 has identified several gaps that need for further investigations with standardized methodologies and measurements in various settings, including clinical, educational, and hospital contexts, as well as surveys on large and diverse populations to improve our understanding of the near point of convergence and its implications for different age groups. Additionally, there is a need for consensus on test methodologies, target selection, and standardized measurements for break and recovery values in near point of convergence studies. Therefore to acquire information about the numerous test procedures and types of targets in NPC, we study various databases to determine the relevancy of our objective.

2. Materials and Methods

The search for the relevant journal was carried out referring through many different records such as: PubMed, PubMed Central, ResearchGate, and form other internet sources.

2.1. Study selection

Our study included various test methodologies and types of targets used in near point of convergence measurement. For this the detailed information regarding the selection of papers and other categories is described in **Table 1**.

Table 1: Study selection of NPC

Study year	Study Design	Age group	Settings	Context
1886-2023	Cross sectional Study, Descriptive mixed model study, Retrospective Study, Descriptive study, Correlational study, Systematic review, Meta-analysis.	Reviewed in less than 5-85 year old age group	Elementary School Children's, Clinical settings, Surveys on small and large Population, Hospital settings.	Near point of convergence, Test Methodologies, Target selection, Break and recovery values Measurements.

Table 2: Synopsis of studies regarding evidences on various methodologies and target selection for NPC measurements

Reference	Publication type	Methodology	Break	Recovery	Target selection	Recommended
Duane A.A[17]	Clinical review	Clinical sample of 8-12-year-old children with near-extrinsic exophoria and one clinical sign of CI,	7.5cm	-	Pen-Point, Fine dots, Dots on a large card	NPC more prevalent than a diminished Positive Fusional Convergence (PFC) (27% vs. 17%).
Siderov and colleagues[18]	Cross sectional study	Study on (n=28) subjects of 20-85 years old into (n=14) presbyopic group, (n=14) younger non-presbyopic group.	NPC (break) was significantly less remote than the NPC (recovery).		NPC was measured to the nearest 0.5 cm using three targets: the RAF rule, the sharpened tip of a pencil and the tip of the examiner's index finger.	NPC measured using the RAF rule, remains consistent for subjects with minimal accommodation, with a slight accommodative influence in non-presbyopic subjects.

Table 2 Continued…						
Scheiman M et al[19]	Comparative study	(n=175) subjects with normal binocular vision and (n=38) subjects with convergence insufficiency	5cm	7cm	Accommodating target, penlight 10 repetitions, and penlight with red and green glasses.	Regular assessing NPC using an AT, and if, borderline, then test should be repeated with PRGG.
Hamed MM et al[13]	Cross sectional study	(n=124) of age group 19-30 years were divided into symptomatic and asymptomatic group	71.4% of symptomatic participants had an NPC > 9.5 cm		small isolated letter "E" of approximately 20/30 size on a metal rod was used	NPC is helpful in the differentiation of symptomatic from asymptomatic subjects.
Mucha A et al[20]	Cross sectional study	(n=64) patients aged 13.9 ± 2.5 years and seen approximately 5.5 ± 4.0 days after a sport-related concussion, and 78 controls were administered	5cm	5.8cm	9-point font size objective, the battery-powered Bernell Vergel™ (Mishawaka, IN)	Pursuit eye movements and NPC distance, along with saccades, should be included in the ocular motor assessment of concussions.
Jung UN et al.[14]	Descriptive Study	136 elementary school children, aged 8–13 years, were assessed	Maximum in 9yrs (6.44 ± 1.90)cm	Maximum in 9yrs (9.25 ± 2.08) cm	Standard push-up techniques using a fixation stick (Bernell, Mishawaka, IN, USA).	No statistically significant correlations between the school childrens' ages and NPC
Tiwari N[21]	Retrospective Study	(N=130) subjects of age 20-35yrs were examine to see the impact of therapy on computer users suffering from convergence insufficiency	13.81cm	15.03cm	A long scale and an object Pen–accommodative target	CI can be caused by long hours of work, headaches, or strains, and early diagnosis is crucial for effective treatment and symptom alleviation.
Hashemi H, Pakazad R et al.[22]	Cross sectional study	Study involved (n=3851) Iranian rural population subjects (n=3314 responses) age group <5-70 yrs. to determine the distribution of NPC by age, sex, and refractive error over one year.	NPC was 8.42 ± 2.94 cm in whole population		Best optical correction: 6/12 single target on a Gulden fixation stick held at midline measured 5 times	The study found a higher NPC break point, with age being the most significant factor affecting it, suggesting accurate measurements can aid in diagnostic and treatment interpretation.
Hashemi H et al[2]	Cross sectional study	(n=1,357) subjects were analyzed in 18->30 yr age group	7.25	7.48	Accommodative target (near Snellen chart). push-up method and an Astron Accommodative Rule (Gulden Ophthalmics, Elkins Park, PA).	The study found lower NPC values in this age group, suggesting clinicians should consider age and sex when evaluating CI symptoms and binocular vision dysfunctions, and the Hofstetter formula.

Table 2 Continued…						
Baskaran AA et al[23]	Cross sectional study	Asymptomatic Subject Study • 60 asymptomatic subjects (18-25 years) • Grouped into emmetropes, myopes, and hypermetropes.	[6.37±0.74using PR in (Myopes [10.30±1.45 Using RG in Hypermetropes	[8.70±1.97] using PR in Myopes) [13.13±1.20 5 Using RG test in Hypermetropes.	Royal Air Force (RAF) rule, Pencil Rule (PR) and penlight with red green glasses (RG) using standard techniques.	RG yields more receded results in hypermetropes. PR test yields better results in myopes.
Wijayati, M.P.[24]	Correlational study	• Majority female (56%). • Age range: 7-24 years. • Median activity: 78 hours/week. • Myopic parent: 27.2%.	r = -0.332, p<0.001	r = -0.335, p<0.001).	-	NPC Correlation Inversely Influences Myopia Progression
Bandhu S D et al[25]	Cross sectional study	The study aimed to measure NPC in a North-western Indian population to determine their association with IPD. In young adults of 18-22 years age group.	Overall response 6.14-7.02cm (Male-female)		Push-up method with the Royal Air Force (RAF) Rule measured 3 times	Weak Correlation Between NPC and IPD.

*AT: Accommodative target; PRGG: Penlight with red and green glasses; PR: Pencil rule

3. Discussion

In this article, we review on various test methodologies and types of targets used in near point of convergence measurement. Duane AA defines the maximum power of convergence as the angle created by two optical lines when both eyes are turned to their full extent or the closest possible convergence point.[17] This location is known as the fusion near point of convergence or simply the near point of convergence. He explained that in adults, a discrepancy of 1.5-2" is considered normal. Children have a stronger point of convergence, and the distance between them may not exceed 1". It is considered that a gap of less than 1" shows excessive convergence power, whilst one of more than two and a half inches implies inaccuracy.

Near point of convergence break and recovery assessment is a crucial component of a standard eye exam for the diagnosis and treatment of CI. When one or both eyes deviate from fixation, or when both eyes re-establish triangulation on the target, the examiner records the objective values of break and recovery to binocularity. The nearest 0.5 cm is used to measure all reading.[18,26]

Research suggests repeating the near point of convergence (NPC) test for diagnosing convergence insufficiency, but there is no consensus on the frequency. Some researchers propose a protocol of 10 repetitions Bandhu et al.[25] suggest that three repetitions yield better results using an RAF rule. However, one study reported that NPC break and recovery values do not significantly differ when measured multiple times during the same testing session.

3.1. NPC measurements in Children (<5yrs to 18) yrs.

According to Hasehmi and Pakzad, children under 5 years have an NPC of 5.63±1.90, whereas those aged 6-20 years have an NPC of 6.61±2.60.[22] Hayes discovered NPC values of 3.3, 4.1, and 4.3 cm in kindergarten, third, and sixth grade students. In a study by Rouse and Borsting, the average age was 13.9±2.5 years, with an NPC break of 5 and a recovery of 5.8 cm.[12] Jung UN observed an NPC break of 6.44 ± 1.90 and recovery of 9.25 ± 2.08 (cm) in a 9-year-old cohort.[14] Chen reported 1.9 cm in the age range of 1-18 years. Maples found an average NPC break of 5.0 cm or less in elementary school children. Jiménez et al. reported an average NPC break of 5.2 cm using a penlight.[28]

3.2. NPC measurements in adults (19-85) years

Siderov observed that NPC (break) was substantially less remote than NPC (recovery) in 20-85 years,[18] while Hamed MM reported that 71.4% of symptomatic participants had an NPC >9.5±4.5 cm in 19-30 years of age.[13] Furthermore,

Tiwari N's study demonstrated an NPC break of 13.81cm and a recovery of 15.03cm in the 20-35 age range.[21] Hashemi and Pakzad found NPC values of 8.32±2.45 (21-30 years) and 10.44±3.07cm (>70 years).[22] Hashemi and Pakbin discovered an NPC break of 7.25 and recovery of 7.48 in 18-30 years.[2] Baskaran AA reported an NPC break of 6.37±0.74cm and recovery of 8.70±1.97cm in myopes.[23]

The literature found in convergence insufficiency measurements, target selections, assessment, and treatments are inconsistent. Cooper and Jamal reviewed NPC, a clinical examination with varying methodologies.[30] Variables like size, measurement point, speed of movement, and patient's response contribute to expansive pass/fail standards, as suggested by various sources.[17,29,31]

Our study reviews on various target selection methods for NPC assessment, including Royal Air force, pencil tip, pencil rule, Penlight, Tip of examiner index finger, penlight with red and green glasses, Bernell Vergel™, Pen accommodative target, Push up methods, Gulden fixation stick. We found that the target had a concentration on the least break value of (5cm) using 9-point font size objective, the battery-powered Bernell Vergel™ (Mishawaka, IN) and maximum value of (13.81cm) using a long scale and Pen accommodative target. On the other hand the highest recovery point reviewed was (15.03cm) using Long scale and accommodative target and least was (5.8cm) cm using 9-point font size objective, the battery-powered Bernell Vergel™ (Mishawaka, IN). Maples and Hoenes suggest an NPC break score of 5 cm or more should differentiate symptomatic from less symptomatic pupils.[9] von Noorden et al defined an exceedingly close near point of conversion (NPC) as <5 cm, while an NPC >10 cm is defective.[32] In 36% of 58 studies, a decreased NPC was a crucial diagnosis.[15]

A study conducted by Adler et al. utilizes a penlight, pencil rule, fingertip, and line on a card to analyze NPC in various age groups from 6-30 years.[33] Scheiman et al. investigated NPC using accommodative target with a single 20/30 letter on 175 optometry students of age group 22-37 year age group and yield a statistically significant difference between the target types.[19] The Pennsylvania optometric association developed a plastic washable near-point test card (1955) measuring 7.5 inches by 5 inches. The card features figures, reading material, and illiterate E's on one side and grids in circles (vertical and horizontal) on the other. This is a sort of target selection that is read in concept, but there is no evidence to prove its reliability. In contrast, Bandhu SD utilizes the Royal Air Force scale, and the distance IPD was measured using a ruler and auto-refractometer in his cross-sectional study on NPC and their association with IPD in a North-western Indian population aged 18-22 years.[25] The correlation between IPD and NPC was low (0.18).

4. Limitation

The review highlights the need for standardization in measuring NPC and the importance of considering the limitations of various methodologies and target types. Future studies should aim to address these limitations and provide a more comprehensive understanding of NPC and its role in diagnosing and managing convergence insufficiency.

5. Conclusion

Regular NPC assessments are essential for diagnosing CI. Studies indicate that using a long scale and accommodative target results in higher NPC values compared to other methods. NPC evaluation should account for factors such as age, interpupillary distance, repetition, and text size. Research shows that convergence declines after 20–40 years, emphasizing the need to consider age differences in assessments. Further studies are needed to compare the effects of target repetitions, testing distance, and font sizes across different age groups and individuals with high near-work demands. Additionally, there is a need to standardize NPC assessment protocols, investigate age-related changes, evaluate the impact of near work, integrate technological advancements, and optimize target characteristics to enhance diagnostic accuracy.

6. Source of Funding

None.

7. Conflict of Interest

None.

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